Chapter 7: Models for Other Consequences

Health effects and costs strongly influence the choice of an EMF mitigation policy in our models. In this section we describe the estimation of two other consequences of EMF policies that have a significant impact on decisions: Property values and outages. We also briefly summarize models of the remaining consequences that have little impact on EMF mitigation decisions.

7.1 Property Values

Because so little is known about the property value impact of electromagnetic fields exposure, the property value model is highly scenario driven. It divides property values impacts into those due to an EMF effect and those due to a non-EMF effect, e.g. due to aesthetics, noise, and radio interference. Most high-quality property value studies show some depreciation of properties near transmission lines, though much less is known about distribution lines. As a benchmark, the high-quality property values studies suggest that there is a property value reduction of around 5% for properties near transmission lines (see Hamilton and Schwann, 1995; Gregory and von Winterfeldt, 1996). It is impossible to determine how much of this impact is due to EMF.

To better understand whether it is feasible to obtain high quality depreciation estimates for home near powerlines in California and to determine what effort would need to be made to disentangle EMF and non-EMF effects, we conducted a property value feasibility study. To initiate this effort, we issued a “mock” Request for Proposal (RfP) that laid out the goals and requirements for a high quality property value study. We called it a “mock” RfP, because the intention was not to fund this study, but to obtain insights about its design, limitations, and cost. The mock RfP was reviewed by the SAC and all comments were incorporated in the revisions. The revised RfP is shown in Appendix G.

Initially, the RfP was sent to only one “contractor,” Parkcenter Reality Advisors, a well-known Southern California real estate appraisal firm. This contractor was chosen, because SAC members concerned with property values considered real estate appraisers to be best qualified to conduct such a study and because they had no ties to the utility industry. Parkcenter Reality Advisors responded with a proposal (see Appendix G) that was based on a fairly simple case-control appraisal strategy, without any clear effort to address EMF vs. non-EMF issues or any other complicating issues stated in the RfP. Parkcenter Realty Advisors estimated that the effort would take six months and cost $279,000.

Together with CDHS staff we conducted an internal review of this proposal and found that the proposed study could not possibly resolve the property values debate that motivated this effort. We challenged Parcenter Realy Advisors to revise their proposal (letter from Decision Insights, Inc., Appendix G), but they responded that the current methods were not capable to do so (letter from Parkcenter Realty Advisors, Appendix G).

To close this issue, we sent the RfP to one of Decision Insights' consultants, Dr. Robin Gregory. Dr. Gregory is a nationally known environmental economist, who had conducted an extensive secondary review of the property values literature as it relates to EMF (see Gregory and von Winterfeldt, 1996). He also was program director of the Decision and Risk Management Program of the National Science Foundation and has developed a good appreciation of what research projects can and cannot do for the amount of effort proposed. We asked Dr. Gregory to draft an alternative proposal that was more responsive to the original RfP. His proposal, which is included in attachment G, includes multiple methods and pays close attention to the EMF vs. non-EMF issue. He estimates the project time at 2 years and the cost at $800,000. However, even his proposal includes many caveats that current methods may not be able to disentangle the EMF effects on property values from the non-EMF effects.

The cost and time frame made it impossible to conduct a property values study as part of the current project. Without this study, we used a highly parameterized approach that used a low, medium, and high scenario for property values effects. Property value impacts are expressed as percent depreciation or appreciation. The scenarios consider the immediate property value impact of EMF mitigation. Is also possible to consider the impact due to results of future research. For example, one might expect further property depreciation, if research proves an EMF-health link. However, unless the probability assigned to such a research result is high, the effect of research outcomes is small relative to the effect of mitigation. The default setting in the ANALYTICA models is therefore to ignore property values appreciations or depreciations due to research outcomes.

To assess the property values impacts that can occur as an immediate result of mitigation, the user needs to specify the following parameters:

$d_{EMF}(M_i)$	percent immediate depreciation or appreciation due to an EMF effect for mitigation alternative M_i,
$d_{non-EMF}(M_i)$	percent immediate depreciation or appreciation of the property values due to non-EMF effects for mitigation alternative M_i,
v	average property value
n	number of homes adjacent to the powerline per mile.

With these inputs, the per-mile property appreciation or depreciation can be calculated in constant, non-discounted dollars as

$$D(M_i) = v*n*[(d_{EMF}(M_i) + d_{non-EMF}(M_i)$$

The values of v and n can be changed by the user, depending on the specific line segments and land use characteristics. A typical transmission line passing through a dense, suburban residential area might have some 50 houses on each side per mile (n=100) with an average home value of $200,000. Several of the ANALTYICA® models use the default values shown in Table 7.1.

Regarding appreciation or depreciation percentages, users have two options: they can either choose from three scenarios (low, medium, and high) or develop their own depreciation and appreciation tables. In the transmission line retrofitting model, higher depreciation or appreciation values are used throughout (by a factor of 2). All retrofitting models use appreciation, when a mitigation alternative eliminates the negative impacts on property values or when research is negative, depreciation in case of positive research. Also note that mitigation measures that are not likely to affect the perception of the EMF exposure (such as delta configuration or raising the pole height) are not credited with appreciation. New Transmission line models use depreciation for construction that creates new impacts on property values.

Some users prefer to think of property values depreciation as a penalty for those alternatives that created the depreciation in the first place. In this case, the no change alternative and other alternatives that do not clearly change the perceptions of EMF impacts would receive a depreciation penalty rather than a status quo estimate. In contrast, the undergrounding alternative would not receive a property values appreciation benefit, since it simply undoes a past penalty. The user can choose between the forward-looking definitions of depreciations and appreciations and a "switched" calculation that looks backward. In both cases, however, appreciations or depreciations due to research outcomes are expressed in the forward-looking mode.

Table 7.1 Relative Property Value Depreciation/Appreciation Default Values for Primary Distribution Lines

(Impacts are doubled for transmission lines, negative sign indicates appreciation)

EMF Impact	**Low**	**Medium**	**High**
No Change	0%	0%	0%
CompactDelta	0%	0%	0%
Raise Height	0%	0%	0%
Underground	0%	-2.5%	-5%

Non-EMF Impact	**Low**	**Medium**	**High**
No Change	0%	0%	0%
Compact Delta	0%	0%	0%
Raise Height	0%	0%	0%
Underground	0%	-2.5%	-5%

7.2 Outages

There are two criteria related to service reliability: Contingencies and customer interruptions. Both begin with an outage, which occurs because of an equipment failure of a powerline, for example due to a tree hitting the line or due to wind toppling a power pole. An outage of a distribution line frequently leads to customer interruptions. However, because of the redundancy built into the transmission line network, an outage of a transmission line does not necessarily lead to customer interruptions. Yet, utility companies dislike transmission line outages, since they render the transmission system more vulnerable and require re-routing of electricity and changes in load ratings of the functioning lines. Utilities refer to a transmission line outage that does not lead to a customer interruption as a "contingency." The service reliability models calculate both the expected contingency time for the lifecycle of a line per mile and the expected total customer interruption time.

Contingencies

Contingencies were calculated only for transmission lines. Originally we had used a data set from the Canadian Electricity Association 1995, 1996) and Billinton et al. (1995). These data generally showed that outage frequencies were about the same for overhead and underground designs, but that outage duration was much longer for underground designs. The use of this data set was strongly criticized by some stakeholders and reviewers of our draft report. We managed to obtain another data set from the California Independent Systems Operator, which reported outage frequency and duration per circuit mile for eleven years for about half the California transmission line system. Unfortunately, there are very few underground transmission line circuits in this data set. Nevertheless, we decided to use the California data, because of the strong concerns expressed by stakeholders. To convert the California data, which are reported by circuits to per-mile figures, we estimated that a typical circuit has about 20 miles. Table 7.3 shows the frequency of outages per year and per mile for three different voltage classes.

Table 7.3: Frequency of Outages Per Mile and Year (California Data)

Line Type	Frequency/Mile/Year
UG-69kV	0.011
UG-115kV	0.010
UG 230kV	0.010
OH-69kV	0.031
OH-115	0.026
OH-230	0.024

Note: UG standard for underground, OH stands for overhead

The other key model component is the average outage duration, once an outage occurs. The California data are summarized in Table 7.4.

Table 7.4: Average Outage Duration, if an Outage Occurs (California Data)

Line Type	Outage Duration/Occurrence
UG-69kV	6.1 hours
UG-115kV	17.3 hours
UG 230kV	21.1 hours
OH-69kV	8.5 hours
OH-115kV	7.1 hours
OH-230kV	6.8 hours

Using Tables 7.3 and 7.4, we can calculate the expected annual contingency hours per mile of transmission lines by multiplying frequencies with average outage durations. These results are shown in Table 7.5

Table 7.5: Expected Annual Contingency Hours per Mile of Line

Line Type	Hours/Mile/Year
UG-69kV	0.067 hours
UG-115kV	0.173 hours
UG 230kV	0.211 hours
OH-69kV	0.264 hours
OH-115	0.185 hours
OH-230	0.163 hours

In comparison, the Canadian data were higher (by a factor of about 2-3) for underground outages, primarily because of much higher durations. The Canadian data were much lower for overhead (by a factor of 6-7) primarily because of lower outage frequencies. Part of this discrepancy may be due to the fact that the California data include all sources of outages, for example at substations, while the Canadian data were exclusively for outages due to line or cable failure.

Using the numbers in Table 7.5, the model then calculates the lifetime contingency hours by multiplying the annual per mile numbers by the number of miles of line (depending on scenarios) and the expected lifetime of the line (default: 35 years).

Customer interruptions – transmission lines

Because of the redundancy built into the transmission line network, only a fairly small percentage of outages will lead to customer interruptions. However, if they occur, they can last for a long time and will affect many customers. The percent of outages leading to customer interruptions and the number of customers interrupted are captured as scenario variables with the following default settings for transmission lines:

Percent of transmission line outages leading to customer interruptions:

1. Low: 2%
2. Medium: 4%
3. High: 8%

Number of customers interrupted:

1. Low: 10,000
2. Medium: 50,000
3. High: 100,000

With these inputs, the model calculates the total customer interruption hours per year and per mile of transmission line. For example, for a 115kV overhead line, and using the medium scenario settings, this would result in

Total Customer Interruption Hours = $0.185 * 0.04 * 50{,}000 = 370$ (h/mile/year).

Customer interruptions – distribution lines

California utilities collect and report statistics on customer interruptions annually to the California Public Utilities Commission. The most important statistic is the Systems Average Interruption Duration Index (SAIDI) which is expressed in minutes per customer per year. The SAIDI is calculated by adding each customers' minutes of interruption in a given year and the dividing this number by the number of utility customers.

Utilities do not report SAIDI data separately for overhead and undergound lines. As part of this project, we asked several utilities to provide us with separate SAIDI account for overhead and underground parts of their distribution system. Four utilities responded, and the data are shown in Table 7.6.

Table 7.6 SAIDI Data from Three California Utilities

(Minutes of customer-interruption per year, including major excludable events)

	Overhead	**Underground**
Southern California Edison	81.1	59.3
San Diego Gas and Electric	38.2	41.7
Modesto Irrigation District	31.4	4.6
PG&E	24.1	11.7

The San Diego Gas and Electric SAIDI data include planned outages, the others don't. The Modesto Irrigation District SAIDI data are based on a very small and relatively new underground portion of their system. The model uses the Southern California Edison SAIDIs as a default, since it was based on the largest set of available data when the model was built (the PG&E data were not available when the model was built).

To calculate total customer-interruption hours, we need to know the number of customers interrupted, if a distribution line fails. On average, there are about 50 customers per mile of primary distribution line. However, there will be some areas with a much higher population density. We therefore let the customer choose between three values: 50 (low), 100 (medium) and 500 (high) customers per mile of distribution line, who would be interrupted by an outage.

For example, for a 4 mile stretch of a primary distribution line, the default values (Southern California Edison SAIDIs and 100 customers affected per mile) would give an estimate of

Total Customer-Interruption Hours = 100∗81.1/60 = 135 hours/year.

7.3 Criteria with Minor Impacts

Similar models were built for all other criteria. The general strategy was to conduct bounding calculations that would tend to increase the possible impact of the criterion. By and large, this has not occurred. Instead the models on all other criteria show very minor impacts relative to the four criteria discussed previously in this report (health effects, costs, property values, and outages). Users who do not agree with this conclusion, can easily change the model parameters and determine how much “tweaking” of the ANALYTICA® parameters it would take to create a significant impact on any given criterion.

Because these criteria show little impacts on the policy alternatives, we will discuss these models only briefly. For more extended discussions, the model users are referred to the Analytic documentation in Appendix A.

Worker health – EMF

There are two criteria for worker EMF risks: leukemia and brain cancer. The calculations for both health endpoints are identical. We exclude Alzheimer’s disease as it generally applies only to people above the age of 65. For both criteria, the models first estimate exposure and time of exposure, then use the same dose metrics and dose-response functions as in the public EMF risk analyses. The key difference compared to the public EMF risk analysis is that the exposure estimates are not modeled but extrapolated from existing data, and that the exposure is mediated through a variable “number of worker years per mile” of work on transmission or distribution lines. This variable allows us to create the equivalent of sustained exposure.

The exposure default values are for linemen while working on live lines. The numbers are expressed in milliGauss (mG) TWA and in percent exceedances of binary thresholds. The estimates are from Bracken et al. (1990) and Theriault et al. (1994). Bracken et al. (1990) do not distinguish between underground and overhead work, but they have an extensive database that was used to calibrate exposure from lines. The data by Theriault et al. (1994) suggest that underground live work involves about twice the average exposure than overhead line work. As a first approximation, the model uses Bracken et al. (1990) data to estimate overhead exposure and multiplies it by 2 to estimate underground exposure:

Overhead, average exposure: 2 mG
Overhead, > 2 mG: 50%
Overhead, > 5 mG: 25%
Overhead, >10 mG: 10%

Underground, average exposure: 4 mG
Underground, > 2 mG: 100%
Underground, > 5 mG: 50%
Underground, > 10 mG: 20%

These exposures are used in conjunction with the dose-response functions described in Chapter 5 to calculate relative risk for linemen who work 100% of time on a live line. However, linemen typically work only a small fraction of their time on live lines, so an adjustment has to be made to determine the total number of worker-years on live lines. This adjusted number is then divided by the number of miles to obtain an estimate of the number of worker years of live-line work per mile.

To determine the number of worker years of live line work per mile of line, we obtained the total miles of overhead and underground transmission and distribution lines of one major California utility as:

OH-TL: 18,409
OH-DL: 180,000
UG-TL: 108
UG- DL: 40,000

Second, a consultant (Gray, 1998) estimated the number of transmission and distribution linemen in this utility:

Transmission Linemen: 50 (low), 75 (medium), 100 (high)
Distribution Linemen: 3000 (low), 3250 (medium), 3500 (high)

Third, the same consultant estimated the percentage of time that workers would work at or near energized lines:

Transmission: 1% (low), 2.5% (medium), 5% (high)
Distribution: 10% (low), 20% (medium), 30% (high)

This information was used to calculate first the total worker-years spent at or near energized lines, and second, to calculate the worker-years per mile of transmission and distribution lines:

Transmission: 0.000027 (low); 0.0001 (medium); 0.0003 (high)
Distribution: 0.0014 (low); 0.003 (medium); 0.0048 (high).

By multiplying the risk of one worker continuously conducting live-line work with the worker-years per mile we can determine the worker risk increase per mile of line. For example, the worker EMF risk per mile of distribution line was calculated as 0.000000033 cases per mile of distribution line per year. This risk is very small and constitutes a minor impact on the policy decisions.

Fatalities and injuries due to fires

The calculations for fatalities and injuries are very similar. We report fatalities only. The key numbers in this calculation is the total number of deaths in California due to fires - an average of 319 deaths (and about 5,000 injuries) per year for a ten year period in the eighties (California State Fire Marshal, 1988). The percent of these deaths attributable to powerlines is very uncertain. We therefore used conservative estimates. Multiplying total fire deaths in California with the percent of deaths attributable to powerlines and dividing this number by the miles of overhead lines determined the annual fire fatalities per mile as a major model input.

According to the National Fire Data Center (1978) about 11% of all fires are due to electrical distribution. This includes overhead and underground transmission and distribution. It is unclear whether this percentage includes wiring in buildings, but the 11% figure is certainly close to an upper bound for the percentage of fires due to distribution and transmission lines. We further assume that all fires are due to overhead (OH) lines, none to underground (UG) lines and that the percent of fires is identical to the percent of fatalities (injuries).

To reflect the uncertainties in the estimation of this percentage, the user can use three settings:

Low:	1%
Medium:	5%
High:	15%

According to data provided to the California Public Utilities Commission (Utilities Report to the CPUC, 1997), investor owned utilities (IOUs) operate some 250,000 miles of overhead distribution lines. According to the California Energy Commission (1999), the IOUs own approximately 78% of California's transmission and distribution system (California Energy Commission, 1999). Therefore, California has approximately 320,000 miles of overhead distribution lines. We add to that 43,000 miles of overhead transmission lines to a total of 363,000 miles of overhead lines.

With these inputs it is straightforward to calculate the expected number of fire fatalities or injuries per mile of overhead line. For example, with 5% of fire fatalities due to overhead lines

$$\text{Fire Fatalities} = 319 * 0.05/363{,}000 = 0.000044 \text{ (fatalities/mile/year).}$$

$$\text{Fire Injuries} = 5{,}000 * 0.05/363{,}000 = 0.0007 \text{ (injuries/mile/year)}$$

Fatalities and Injuries due to Pole Collisions

The key variable in this model is the fatality risk per pole. It depends on the number of fatalities (injuries) from utility pole collisions in California (n), the percent of utility poles that are electrical utility poles (p), the total miles of overhead (OH) transmission and distribution lines (m) and the number of poles per mile (ppm). The fatality risk per mile for overhead design is the product of the fatality risk per pole times the number of poles per mile. The fatality risk per mile for undergrounding an existing overhead line is the residual risk, once the poles for overhead distribution are removed. If all poles are removed, this residual risk is zero. However, some poles may remain, to support existing structures or non-electrical utilities.

Between 1994 and 1997 there were, on average 126 automobile crashes with utility pole collisions in California, with 69 fatalities, 49 injuries, and 8 cases with property damage only (see Table 7.7).

Table 7.7: Fatality and Injury Risks from Pole Collisions in California

	1994	1995	1996	1997	Average
Fatal	75	69	63	68	**69**
Injury	53	39	58	44	**49**
No Injury	15	10	5	3	**8**
TOTAL	**143**	**118**	**126**	**115**	**126**

Fatal Accident Reporting System (FARS), 1994, 1995, 1996, 1997. US Department of Transportation, National Highway Safety Administration. FARS Web Site: www-fars.nhtsa.dot.gov, FARS Query System, February, 1999.

The U.S. Department of Transportation FARS data distinguishes between light posts, sign posts, and utility posts, but it does not distinguish between electrical and other utility posts (telephone and cable). However, one can assume that most utility posts are electrical utility poles or poles that carry multiple utility lines. The user can choose between three values: Low (80%), Medium (90%), and High (100%).

We estimated the total miles of overhead lines in California as 363,000 miles (see Chapter 2). Not all poles will necessarily be removed when an overhead line is undergrounded. For example, poles that carry streetlights will either remain to provide light, or they will be replaced by light poles. The model lets the user choose between 50% (low), 75% (medium) and 100% (high) pole removal. The number of poles can vary as a function of the weight of the line and other factors from 10 per mile to 20 per mile. As a default, the model uses 20 poles per mile (Gray, 1998).

For example, considering the medium default values, the fatality risk per mile is calculated as follows:

Fatality Risk = 69*0.90/363,000 = 0.0002 (fatalities/mile/year).

Correspondingly, the fatalities risk after undergrounding are either 0 (100% pole removal), 25% or 50% of these numbers. The injury risks are calculated simply by replacing the number of fatalities (69) by the number of injuries (49). While these risks are fairly small, they occasionally show up in the ANALYTICA® calculations, when considering long stretches of line and 35 years of operations.

Electrocutions – Worker Fatalities

This model estimates annual number of worker electrocutions in California due to contact with overhead lines and the number of worker electrocutions in California due to contact with underground lines. It converts the annual number of electrocutions into a number of electrocutions per mile of overhead and underground lines by using the respective total miles of overhead lines and the total miles of underground lines in California. Further calculations extrapolate this result to the lifetime of the line (default: 35 years) and reductions in life expectancy.

This model includes electrocution risks both from line workers and other workers that may come in contact with power lines. The best statistics for this purpose come from the California Division of Labor Statistics Research (1998):

Table 7.8: Worker Fatalities due to Contact with Electric Current (1992-1996)

	OH Lines	Appliances	Other
1992	13	7	5
1993	10	8	8
1994	10	4	10
1995	11	2	10
1996	14	3	10
Av.	**11.6**	**4.8**	**8.6**

None of the labor risk statistics bracket out underground cables as a source of worker electrocutions. The "Other" category of the California Division of Labor Statistics and Research includes contact with wiring, transformers and other electrical components. One source (CPUC, 1985) list 2 electrocutions due to contact with underground lines in one year, but it is unclear whether these were workers or members of the public. The model uses three values -- 0 (low), 1 (medium) and 2 (high) -- for the estimated number of electrocutions due to underground cables in California.

The total miles of overhead lines are estimated at 363,000 miles and underground lines are estimated at 100,000 miles.

With these inputs, we can calculate:

Annual electrocution risk (worker) per mile of OH = 11.6/363,000 = 0.000032,
Annual electrocution risk (worker) per mile of UG = 1/100,000 = 0.00001.

Electrocutions – Public Fatalities

This model builds on the electrocution rate per 100,000 population in the U.S. (about 0.30) and calculates the number of electrocutions in California by multiplying the rate by 300 (30 million people in California). It then allocates a percentage of this number to overhead lines and to underground lines. Using the respective total miles of overhead and underground lines the model then normalizes the resulting electrocutions to a number of electrocutions per mile.

The Statistical Abstracts of the United States (1994) state that there were 670 electrocutions in the U.S. in 1990 – a number that has been steadily declining. Using this number results in a rate of 0.3 electrocutions per 100,000 population in the U.S.

Multiplying the electrocution rate by 300 to reflect the 30 million population of California results in 90 electrocutions. We need to subtract from this number the cases of worker electrocutions (see the worker electrocution model) which amounted to 25 cases per year. Thus the net estimate of public electrocutions for California is 65.

Data by the California Division of Labor Statistics Research (1998) suggest that about 46% of worker electrocutions are due to overhead line contact. This is probably an upper bound for public electrocutions, which are more likely to occur in or around the house. The model has three possible values for the percent of electrocutions due to OH lines: 20% (low), 30% (medium), and 50% (high). At 30%, this would result in an estimated 0.30*65=19.5 electrocutions.

Table 7.9: Percentage of Worker Electrocutions due to Contact with Electrical Equipment

	OH Lines	Appliances	Other	Percent OH
1992	13	7	5	52%
1993	10	8	8	38%
1994	10	4	10	42%
1995	11	2	10	47%
1996	14	3	10	52%
Av.	**11.6**	**4.8**	**8.6**	**46%**

Another set of data was made available o the project recently (CPUC, 2000). This data suggests that there is an average of 46 public electrocution deaths per year in California, which is lower than the 65 deaths that we estimated. The same report estimates that 21.6% or ten deaths per year (our estimate: 19.5 deaths) are due to electricity generation substations, transmission and distribution. According to this data set, electrocution deaths due to transmission and distribution would be lower than our deaths per year (less than 10 due to omission of electricity generation and substations). Thus, our estimates are likely to be at the high end.

There is no data that directly identifies electrocutions due to contact with underground cables. A 1985 CPUC report states that there were 2 electrocutions in California in one year due to this type of contact. It is not known whether these electrocutions were public or worker cases. Assuming that one case per year is a public electrocution, this would be 5% of the estimated public OH electrocutions. Using this 5% as a benchmark, the model uses 1% (low), 1.5% (medium) and 2.5% (high) as scenario settings for the percentage of public electrocutions due to underground lines.

There are about 363,000 miles of overhead lines and 100,000 miles of underground lines in California (see above). Using these numbers, we can calculate:

Annual public electrocutions due to OH = $0.30 * 65/363{,}000 = 0.0001$,
Annual public electrocutions die to UG = $0.015 * 65/100{,}000 = 0.00001$.

Construction – worker fatalities and injuries

The construction fatalities (injuries) depend on the number of worker-days of construction per mile and the annual fatality risk for construction workers. The number of worker-days of construction per mile depends on the alternative chosen. In general, undergrounding has the largest number of construction days, but other alternatives like split phasing, raising the pole height, etc, will also involve construction.

According to the Bureau of Labor Statistics (1994), the annual fatality risk from construction is 0.00033. The user can update this number as more recent information or information that is specific to utility construction becomes available. The annual risk of a serious injury is 0.067 (Bureau of Labor Statistics, 1994).

Table 7.9 lists estimates of the number of worker-days of construction per mile for three scenarios (low, medium, high) and each alternative that involves construction. The estimates in the table were obtained from William Gray, a consultant to Decision Insights, Inc. The default is the medium scenario.

Table 7.10: Estimates of Worker-Days of Construction per Mile

	Low	Med	High
Overhead Transmission – Pole:	30	35	40
Overhead Transmission – Towers:	200	250	300
Overhead Distribution – Pole:	15	20	30
Underground Transmission:	1800	3,000	5000
Underground Distribution:	35	40	50

With these inputs, we can calculate the fatality and injury risk per mile of construction. For example:

Fatality risk per mile of UG transmission = 0.00033*3,000/365 = 0.0027,
Injury risk per mile of OH distribution (pole) = 0.067*20/365 = 0.0037.

Property losses due to fires

This model calculates the annual fire property loss due to transmission and distribution lines as a function of the annual total property losses due to fires (about $800 million/year) in California and the percent of property loss due to overhead lines. This percentage is uncertain (an upper bound is about 11% for all electrical distribution sources). To accommodate this uncertainty, the model lets the user input reasonable low, medium, and high values. With the annual fire property loss due to overhead lines for the whole state, and the statewide length of overhead lines, we can then calculate the annual fire property loss per mile of overhead transmission and distribution lines.

According to the California State Fire Marshal (1988), the average property loss due to fires in California is about $800 million (this is a 10 year average of actual property losses reported in California). According to an older report by the National Fire Data Center (1978) about 11% of all fires are due to electrical distribution. This includes overhead and underground transmission and distribution. It is unclear whether this percentage includes wiring in buildings, but the data in the referenced report do not include electrical wiring in buildings as a separate source from “electrical distribution.” In any case, the 11% figure serves to define an upper bound for the percentage of fires due to distribution and transmission lines. To reflect the uncertainties in the estimation of this percentage, the user can use three settings:

Low:	1%
Medium:	5%
High:	11%

We further assume that all fires are due to overhead (OH) lines, none to underground (UG) lines and that the percent of fires is identical to the percent of fatalities (injuries). We estimate the total length of transmission line in California as 363,000 miles.

With these inputs we can calculate

Annual fire property losses per mile of OH line = 0.05*800,000,000/363,000 = $110.

Property losses due to pole collisions

This model estimates property losses due to utility pole collisions. The key variable is collision risk per pole. It depends on the total number of pole collisions in California, the percent of utility poles that are electrical utility poles, the total miles of overhead lines, and the number of poles per mile.

The collision risk per mile for overhead design is the product of the collision risk per pole times the number of poles per mile. The collision risk per mile for undergrounding an existing overhead line is the residual risk, once the poles for overhead distribution are removed. If all poles are removed, this residual risk is zero. However, some poles may remain, to support existing structures or non-electrical utilities.

Between 1994 and 1997 there were, on average, 126 automobile crashes with utility pole collisions in California, with 69 fatalities, 49 injuries, and 8 cases with property damage only (see Table 7.11 below)

Table 7.11: Utility Pole Collisions in California

	1994	1995	1996	1997	Average
Fatal	75	69	63	68	**69**
Injury	53	39	58	44	**49**
No Injury	15	10	5	3	**8**
TOTAL	**143**	**118**	**126**	**115**	**126**

Fatal Accident Reporting System (FARS), 1994, 1995, 1996, 1997. US Department of Transportation, National Highway Safety Administration. FARS Web Site: www-fars.nhtsa.dot.gov, FARS Query System, February, 1999.

The U.S. Department of Transportation FARS data distinguishes between light posts, sign posts, and utility posts, but it does not distinguish between electrical and other utility posts (telephone and cable). However, one can assume that most utility posts are electrical utility poles or poles that carry multiple utility lines. The user can choose between three values: Low (80%), Medium (90%), and High (100%). We estimate the total number of overhead utility lines as 363,000 miles.

Not all poles will necessarily be removed when an overhead line is undergrounded. For example, poles that carry street lights will either remain to provide light, or they will be replaced by light poles. The model lets the user choose between 50% (low), 75% (medium) and 100% (high) pole removal.

The number of poles can vary as a function of the weight of the line and other factors from 10 per mile to 20 per mile (W. Gray, 1998). As a default, the model uses 20 poles per mile.

With these inputs, we can calculate

Annual number of pole collisions per mile of OH line = 126*0.90/363,000 = 0.0003.

To calculate the property losses per mile of line, we need to estimate the average loss per collision. These losses will range from a total loss of a vehicle to minor damage. Using $10,000 as the average collision loss, we estimate the annual property loss per mile to be $3.

Aesthetics

Changing the configuration of powerlines or undergrounding a line can have aesthetic impacts. This model provides a preliminary scale for the aesthetic impacts of powerlines based on several physical features. The aesthetics scale “penalizes” lines that have a more obtrusive appearance (e.g., multiple circuits, lattice structure). The scale is to measure the non-property values impact of aesthetics, for example, due to visual impacts on drivers or pedestrians passing through the area.

At the core of the aesthetics model is a scoring system that expresses how much “worse” the aesthetic impact of a powerline is than a single circuit overhead (OH) configuration for a primary distribution line (without underbuilt secondaries or other service lines). The scoring system is shown below.

	Single Circuit	Double Circuit or Underbuilt
OH-Lattice	3	4
OH-Tubular	2	3
OH-Pole	1	1.5
UG	0	0

Scores for other designs can be judged by reference to these scores.

Tree Losses

This model calculates the equivalent number of lost trees based on the number of trees per mile and the percent reduction of foliage due to overhead lines. According to one utility’s report, there are 400,000 trees that need trimming along 9,140 miles of overhead lines (SDG&E, 1997). This averages out to about 40 trees per mile of OH lines. The user can select from a low (30 trees/mile), medium (40 trees/mile) and high (50 trees per mile) scenario.

Overhead lines limit the growth of trees. However, even without lines, trees would be cut regularly for fire, view, and safety reasons. The user can set the percentage of foliage reduction as a scenario variable from 10% (low) to 20% (medium) to 30% (high). For the new construction scenarios, these reductions are used as a penalty for OH lines. For retrofits, the loss of foliage is considered a sunk cost, and the increase in foliage due to retrofits are considered a benefit.

With these inputs, we can calculate, for example

Equivalent tree loss per mile of OH line = $40*0.20 = 8$.

Air Pollution

This is a fairly complex model that combines the effects of conservation ("Percent Reduction/Increase of Household Electricity Due to Conservation"), tree shading ("Percent Reduction/Increase of Household Electricity Due to Shading"), and line losses ("Relative Line Losses by Alternative") on the "Total Increase/Decrease in Required Supply" of electricity. Current California electricity consumption is about 219 GWh/year (California Energy Commission, 1999). To supply this consumption, approximately 263 GWh/year of electricity need to be produced. The percent increase/decrease in electricity consumption and the relative line losses can be translated into a "Percent Change in Total Electricity Supply." This will lead to approximately the same percent reduction in production at the fossil fuel power plants (about 56% of all California power plants use fossil fuel, see California Energy Commission, 1999). The model assumes that the resulting percentage reduction in the use of fossil fuel plants will lead to the same reduction in pollution generated by these plants. This reduction is then applied to an estimated "Total Annual Cost of Fossil Fuel Pollution in California" to determine an annual and then a "Total Equivalent Change of Pollution Cost."

The default values for the percent reduction/increase of household electricity use due to shading are 0 for overhead lines, and 0 (low), -15% (medium), and –20% (high) for undergrounding. Negative numbers indicate a decrease in household electricity consumption.

The percent reduction/increase of household electricity use due to conservation depends on the policy alternative. In most models it is assumed to be 0. In special conservation models, it is assumed to vary between 5% and 20%. We estimate the average household electricity use per year as 6,000 kWh from data provided by the California Energy Commission (1999). Using data provided by the California Energy Commission (1999), we estimate the total electricity use per year in California as 219 GWh/year. Using data provided by the California Energy Commission (1999), we estimate the total electricity supply in California to be about 263 GWh/year. The relative line loss is calculated in W/ft from the sub-model "Power Loss" (see Chapter 6).

The model counts only the homes directly located near the transmission or distribution lines. The default value is 50 homes on each side of the line for a typical residential segment. The user can control this input for each segment in the "Design and Assumptions" menu.

Using data provided by the California Energy Commission (1999), we estimate the percent of fossil fuel electricity generation to be about 56%. It is hard to estimate the cost of air pollution from fossil fuel power plants. An upper bound might be the cost to eliminate air pollution from fossil fuel power plants. One study in the eighties (Owen et al., 1983) estimated this cost as $10 billion in capital cost and $ 2 billion in annual cost for the nation. Taking ten percent of these estimates to account for California and annualizing the capital cost, the model uses three scenario values of $500 million (low), $750 million (medium), and $1 billion (high). Sage (1999), using a very different methodology, based on emissions and their equivalent costs, estimated the total pollution cost at $854 million per year in California.

For example, assuming a 15% decrease in household energy consumption due to shading, undergrounding a 15-mile stretch of transmission line would save about $95,000 over 35 years. A 20% reduction in household energy consumption due to conservation would save about $160,000 along a stretch of 15 miles of overhead lines over 35 years.

Noise and Disruption

The noise and disruption model calculates the number of disrupted person-days due to construction. A key input is the number of days to build one mile of line. The low, medium, and high estimates were obtained from William Gray, a consultant to Decision Insights, Inc. Other inputs are the number of homes per mile and the average household size. With these inputs one can calculate the number of disrupted person-days per mile.

The following estimates were provided by William Gray (1998, 1999), consultant to Decision Insights, Inc.:

Overhead transmission – pole: 2 (low), 3 (medium), 4 (high)
Overhead transmission – tower: 5 (low), 6 (medium), 7 (high)
Overhead distribution – pole: 3 (low), 4 (medium), 5 (high)
Underground transmission: 30 (low), 70 (medium), 100 (high)
Underground distribution: 3 (low), 4 (medium), 5 (high)

The number of homes per mile is a user determined parameter. In many models, we use a row of single family houses at both sides of the line, with a 50 foot frontage. Allowing for streets, open space, and occasionally wider frontages, we use 50 homes per mile on each side of the line, or 100 homes that would be affected by construction activities. The default for the average household size is 3.

With these inputs we can calculate, for example, for undergrounding a transmission line

Number of disrupted person-days = $70*100*3$ =21,000.

Socioeconomic Impacts

An analysis of the socioeconomic impacts was conducted by a subcontractor, who ran a statewide input-output model to estimate employment and gross regional product (GRP) changes that might result from large investments in EMF mitigation and the associated increases in electricity prices. These models used costs of EMF mitigation of 2 billion per year for ten years. This is at the high end of investments for undergrounding all transmission and distribution lines that produce high fields (see chapter 11). The models also gave credit for the wealth gain associated with property value increases.

Regarding employment, the models estimate that the net impact of reduced household spending due to increased electricity prices is a loss of about 6,435 jobs per year for ten years. Valuing the creation of a job at $10,000 (see Keeney and von Winterfeldt, 1997 for the reasoning), this would correspond to an equivalent loss of $643.5 million per year for ten years or about $2000/mile of transmission or distribution line. However, this decrease is offset by the employment created by the $2 billion investment per year in EMF mitigation. Assuming that an average job costs $50,000/year and that 25% of the investment is for labor expenses, an EMF mitigation program of $2 billion/year would create 10,000 new jobs per year. Subtracting the job losses due to higher electricity prices, this would still be a net increase of 3,565 jobs per year, or gain of about $1,100/mile of transmission or distribution line.

The models estimate that the GRP loss is $255 million per year for ten years. This would be equivalent to a loss of $800 per mile of transmission or distribution line. There would be some offset due to the creation of EMF mitigation activities.

In summary, the per-mile impacts of large EMF mitigation expenditures on employment (-$2,000 to +$1,100) and regional product (-$800 with some offset) are fairly small compared to the cost of major mitigation programs (around $500,000 to $4 million/mile for undergrounding).

Implementation Concerns

Equity and environmental justice will be discussed in Chapter 10. The concerns with practicality and compliance are simple yes-no judgments that are supposed to raise a flag when compliance or practicality issues arise with a mitigation alternative.